Technical Improvements in Fluorine-18-FDG PET Imaging of the Abdomen and Pelvis

Gregory P. Leisure, Hubert J. Vesselle, Peter F. Faulhaber, James K. O'Donnell, Lee P. Adler and Floro Miraldi

PET Facility and Division of Nuclear Medicine, Department of Radiology, University Hospitals of Cleveland, Case Western Reserve University, School of Medicine, Cleveland, Ohio

PET tumor imaging of the abdomen and pelvis is prone to artifacts due to urinary tract activity. A new technique has been developed to reduce such artifacts and enhance study interpretation.

Methods: Thirty minutes after the injection of ^{18}F-FDG, 500 cc 0.45% NaCl were administered intravenously over 30 min and a Foley catheter was placed in the bladder. At the start of imaging (60 min post-injection), furosemide was given (0.3 mg/kg). Prior to imaging the pelvis, the urinary catheter was clamped and saline was introduced retrograde into the bladder until full.

Results: This technique has been used successfully in more than 130 patients, resulting in a marked improvement in study quality and tumor detection.

Conclusion: Hydration and administration of furosemide, along with placement of a Foley catheter in the bladder, have proven effective in eliminating image artifacts originating from the kidneys, ureters and bladder. Backfilling the bladder also provides a well-defined anatomic landmark for study interpretation.

Key Words: positron emission tomography; fluorine-18-FDG; abdomen; pelvis

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Whole-body PET imaging with ^{18}F-FDG has proven to be a sensitive diagnostic tool for the detection of primary and metastatic cancers (*1,2*). However, interpretation of studies for tumors involving the abdomen and pelvis is often hindered by the accumulation of highly concentrated FDG in the urinary tract and bladder, that produces artifacts and can conceal lesions (*2,3*). Various methods have been proposed to alleviate these technical problems. Simple placement of a Foley catheter ensures that urine drains continuously from the bladder but rarely is all concentrated urine completely eliminated. Use of a three-way Foley catheter offers some improvement by allowing the bladder to be continuously irrigated. However, concentrated foci of activity in the bladder are not always completely eliminated and problems caused by urinary activity in the renal pelves and ureters often remain (*4*). In addition, our experience has found that the large bore of a three-way Foley catheter makes catheterization difficult to perform in a routine clinical setting and too painful for many patients to tolerate.

We have developed a technique to address these limitations. A standard Foley catheter is used to facilitate bladder drainage and a combination of hydration and furosemide is used to dilute and clear concentrated activity from the renal collecting system and ureters. In addition, saline is infused retrograde through the Foley catheter to fill the bladder. This creates a full bladder of very dilute FDG activity, a useful landmark of pelvic anatomy. This technique has eliminated nearly all urinary artifacts commonly seen in images of the abdomen and pelvis, thus improving the identification of pathology in these areas.

MATERIALS AND METHODS

The protocol is used for all patients with known or suspected primary or metastatic disease of the abdomen and/or pelvis. Patients are fasted overnight when possible or for a minimum of 4 hr. Following the placement of a 20–22-gauge angiocatheter in an upper extremity, 15–20 mCi ^{18}F-FDG were administered. Thirty minutes post-FDG injection, intravenous hydration was begun with 500 ml 0.45% NaCl using an intravenous pump set at a rate of 1000 ml/hr. At the same time a standard Foley catheter (14 or 16 Fr) was placed in the bladder and connected to a urine collection bag. Imaging was begun at 50–60 min postinjection and acquired over 4–5 bed positions of 10 min duration each. Care was taken during initial patient positioning to ensure that the bladder and lower pelvis were included in their entirety in the last bed position. At, or near, the beginning of torso imaging, 0.30 mg/kg furosemide was administered intravenously, unless contraindicated. Contraindications include anuria and a history of hypersensitivity to furosemide. Midway through the second to last bed position, the urine drainage bag was clamped and the bladder was

For correspondence or reprints contact: Gregory P. Leisure, CNMT, University Hospitals of Cleveland, Division of Nuclear Medicine, 11100 Euclid Ave., Cleveland, OH 44106-5056.

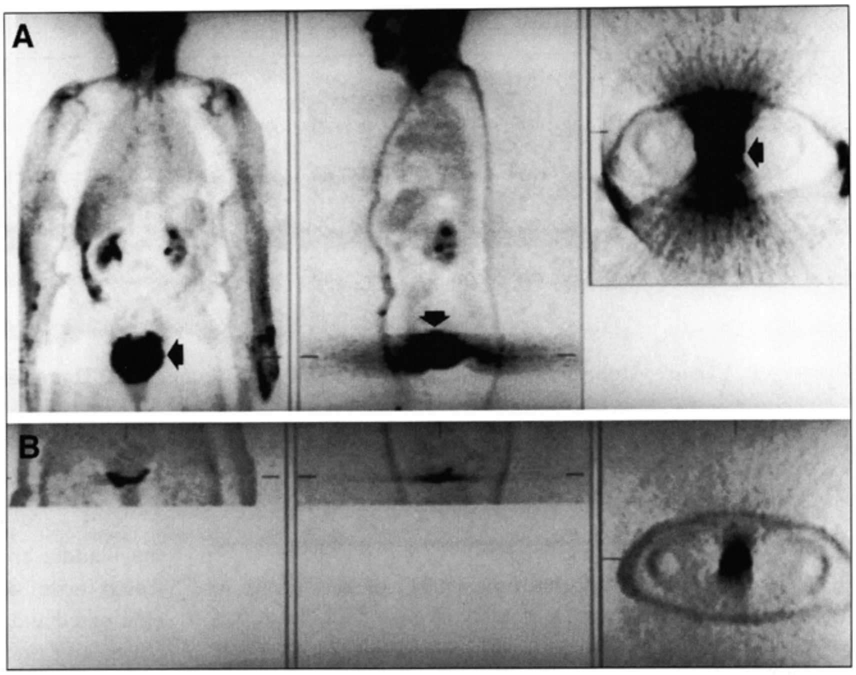

FIGURE 1. (A) Coronal, sagittal and axial image set demonstrating the artifacts that result from not eliminating bladder activity. Note the "blooming and streak" artifact (solid arrows) that severely limits interpretation of the pelvis. (B) Even when the pelvis is imaged immediately post-void, residual urine and accompanying "blooming" artifact persist.

backfilled with saline solution at room temperature through gravity feed using standard intravenous tubing and an 18-gauge needle. The bladder filling was stopped when the patient began to feel a strong urge to urinate or the table had moved to the last bed position. The drainage tubing remained clamped until the completion of pelvic imaging at which point the clamp was released, the bladder allowed to drain and the Foley catheter was removed. The patient then was taken off the table and instructed to void any residual urinary activity from the bladder. Finally, a single 10-min long post-void image of the pelvis was acquired centered on the bladder.

RESULTS

Clinical interest in oncologic applications of whole-body PET has accelerated in recent years. PET is now being used clinically: to assess the presence and stage of tumors; to evaluate the metastatic spread of disease, the response to treatments and tumor recurrence; and to determine whether masses detected by other diagnostic means are benign or malignant in those cases where such a determination is not possible or the data are equivocal.

However, the sensitivity and specificity of tumor imaging are dependent on the imaging technique, the size of the tumor or metastatic lesion, and the avidity of the lesion for FDG. Imaging of the abdomen and pelvis is particularly problematic. There, primarily due to anatomy, pathologic foci of FDG accumulation are often indistinguishable from artifacts or normal structures. The ureters lie lateral to the major lymph node chains of the abdomen and pelvis at the level of the aorta making it difficult at times to distinguish one from the other (*5*). Moreover, the ureters intersect the lymph node chains and are bundled together with the femoral arteries in the area of the bladder. In addition, the fasting (dehydrated) state of patients often causes urinary FDG activity to be concentrated such that "blooming" artifacts occur despite best efforts to empty the bladder prior to imaging (Fig. 1).

DISCUSSION

Although bladder catheterization offers a significant improvement in image quality, activity often pools in the posterior aspect of the bladder (Fig. 2). This can be particularly problematic when attempting to evaluate primary cancers of the rectum, cervix, uterus, and prostate or metastatic tumor sites in the pelvis, especially in areas surrounding the bladder. Irrigating the bladder using a three-way Foley catheter proves

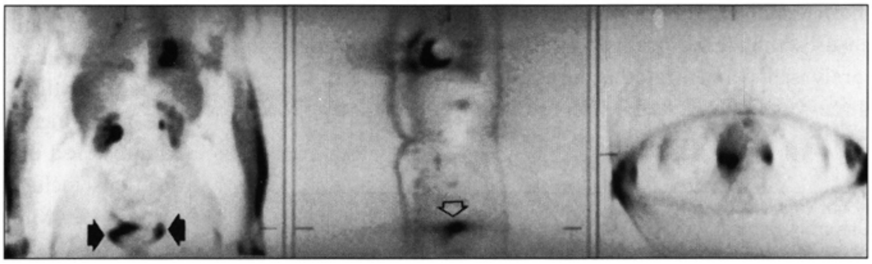

FIGURE 2. Coronal, sagittal and axial image set of a 62-yr-old woman with a history of ovarian carcinoma and status postchemotherapy. The patient was catheterized to drain the bladder but the bladder was not irrigated. The intense foci of activity seen in the pelvis (solid arrows) were all thought to represent residual urine pooling in the bladder. A subsequent second-look laparotomy revealed instead tumor recurrence in the cul-de-sac region, seen on the sagittal image (open arrow).

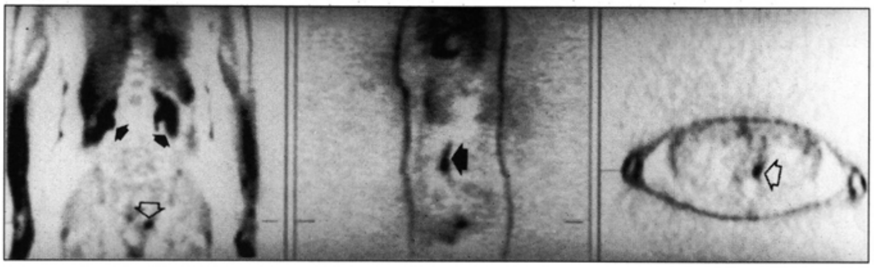

FIGURE 3. Coronal, sagittal and axial image set of a 59-yr-old woman with a history of ovarian carcinoma. The study was performed using a three-way Foley catheter and bladder irrigation only. Note the residual intense uptake in the renal pelves (solid, small arrows) and the confounding foci of activity at the left ureterovesical junction (open arrows) and within the mid-left ureter (solid, large arrow).

more helpful in minimizing the urinary pooling artifact. However, interpretation of the abdomen remains problematic since the technique provides no help in distinguishing metastatic para-aortic lymph nodes from normal ureteral activity (Fig. 3).

The administration of hydration fluids and furosemide has been advantageous in this regard (Fig. 4). The resultant reduction in image artifacts is not easily quantifiable since the clinical nature of the studies performed does not allow comparison studies in the same patients without hydration and furosemide. However, the number of equivocal sites in the abdomen and retroperitoneum is markedly decreased and in most cases artifacts from the kidneys and urinary tract are completely avoided. There are several technical points to consider when administering hydration and furosemide. First, the angiocatheter must be large enough to allow rapid flow of saline during hydration. To date, a 22-gauge catheter has been sufficiently large. If the isotope is injected through the angiocatheter, the catheter port should be changed before imaging or removed from the field of view altogether, since residual FDG in the injection port is a common contributor to image artifact. Second, hydration should be started no sooner than 30 min postinjection since, in our experience, earlier hydration often results in a significant loss of image statistics. Finally, caution should be used in the administration of furosemide and a thorough medical history should be taken beforehand to determine if there are contraindications to the administration of this drug.

The bladder-fill technique we use for pelvic and abdominal imaging has proven to be equally beneficial. Rather than irrigating the bladder through a three-way catheter, saline is introduced retrograde through gravity feed through a standard 14- or 16-Fr Foley catheter, a technique commonly used in ultrasound imaging of the pelvis (*6*). Not only are hot foci eliminated from the bladder by diluting residual activity but, when the catheter is clamped after the bladder is full, a clear anatomic landmark for subsequent image interpretation is created (Fig. 5). In addition, the standard Foley catheter is much easier to place and has been tolerated by all patients to date. Placement of the three-way Foley catheter is both technically difficult to perform and time consuming. Prior to developing the new technique, several studies had to be performed without the benefit of catheterization because either the staff was unsuccessful in placing the three-way catheter or the patient could not tolerate the pain of the procedure.

Several technical points need to be considered when using the new technique. When placing the needle into the Foley catheter, care must be taken to maintain sterility. Cancer patients are often immunosuppressed and prone to opportunistic infections and unsterile technique could be a source for

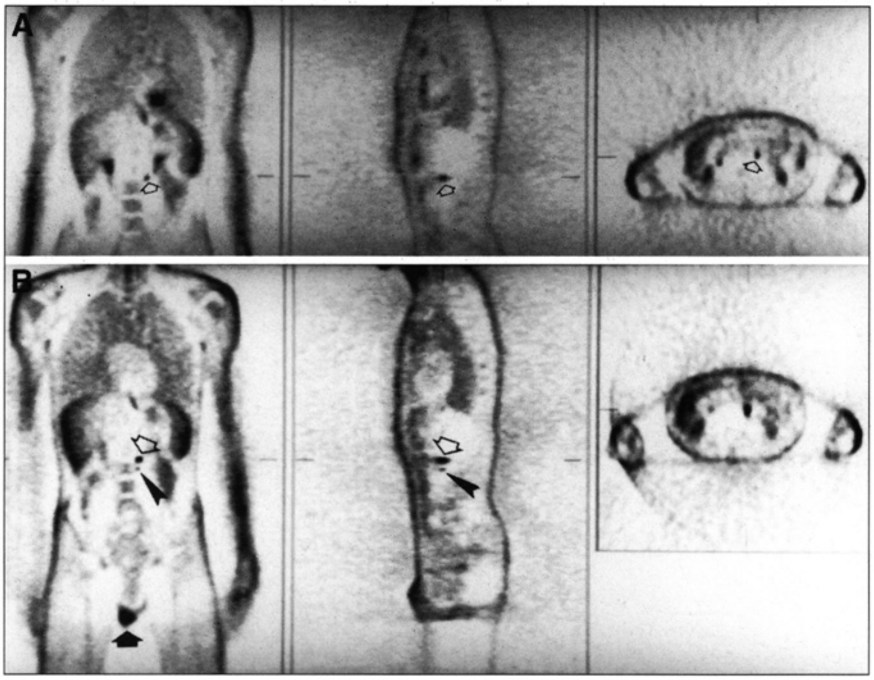

FIGURE 4. (A) Coronal, sagittal and axial image set of a 17-yr-old man with testicular carcinoma. The study was performed with bladder catheterization only. It was unclear whether the focus of activity just medial to the left renal pelvis (open arrows) represented a para-aortic lymph node or normal ureteral activity. (B) The study was repeated 2 wk later using the hydration/bladder fill technique. (B) The study confirmed that the focus seen in the previous study did represent a metastatic lymph node (open arrow). In addition, a second, less intense metastatic node was demonstrated (narrow arrow). The intense uptake in the scrotum (solid, large arrow) represents post-operative changes.

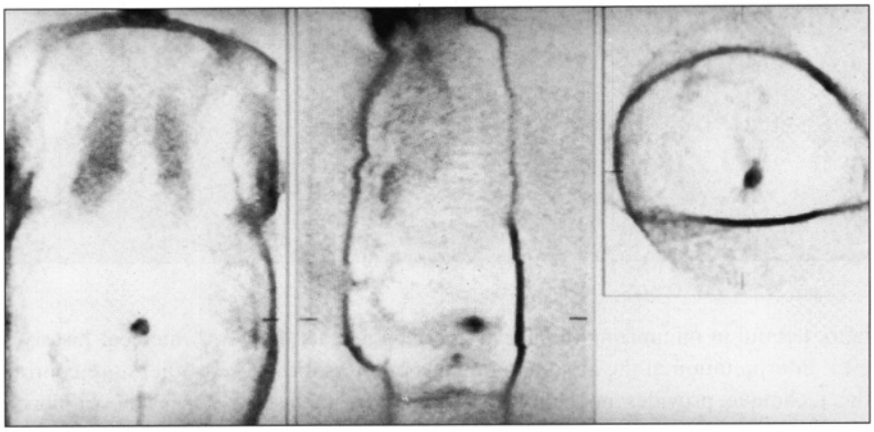

FIGURE 5. Coronal, sagittal and axial image set of a morbidly obese 75-yr-old woman with a history of colorectal carcinoma and rising CEA level. The study was performed using the hydration/bladder fill technique and demonstrates a single focus of increased uptake in the presacral space, which was proven to be a site of recurrence on a subsequent biopsy. Note in this case the complete absence of artifact from renal, ureteral and bladder activity.

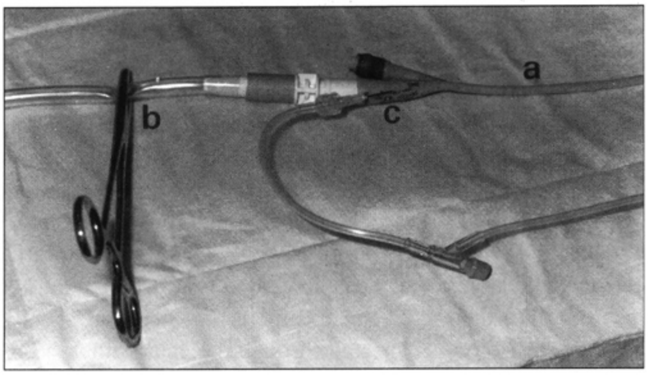

FIGURE 6. Proper setup for the catheterization/bladder fill technique. (a) A Foley catheter is placed in the patient's bladder. (b) The urine collection bag tubing is clamped proximally, and the needle and intravenous tubing used for retrograde bladder filling is inserted at (c).

urinary tract infection. The needle puncture site should be made directly into the Foley catheter at a location between the drainage bag connector and the balloon-fill side arm of the catheter (Fig. 6). If the catheter was not placed specifically for the PET procedure and is not to be removed, the needle can be placed instead into the drainage bag tubing and the bag replaced at the end of the study so as to avoid leakage from the puncture site. Also, fluid should never be forced into the bladder with an intravenous pump; the saline bag should be hung above the patient at a height greater than 1 m and the saline allowed to fill the bladder through gravity only.

Acquiring a static image of the pelvis after the Foley catheter has been removed and the patient has voided has also proven to be an important protocol step. Specifically, this image is a helpful means of distinguishing pathology from structural anatomic artifacts, such as bladder diverticula. (Fig. 7).

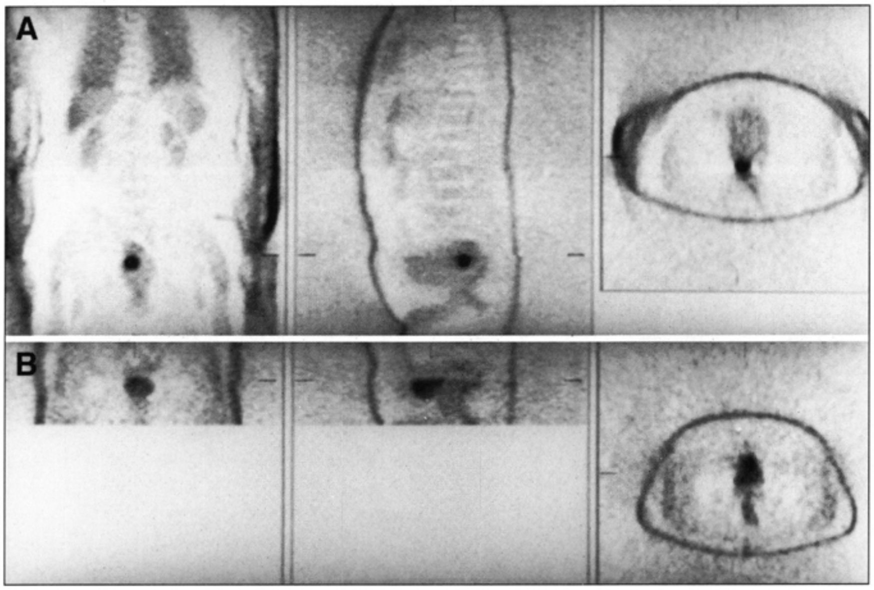

FIGURE 7. (A) Coronal, sagittal and axial image set of a 66-yr-old man with prostate carcinoma. The study was performed using the hydration/bladder fill technique and demonstrates a single, intense focus of FDG accumulation in the posterior aspect of the bladder. (B) On a subsequent post-void image, the intense focus disappears, suggesting the presence of a bladder diverticulum. This underscores the importance of post-void imaging.

CONCLUSION

Poor image quality can result in increased study repeat rates, decreased clinical confidence in abdominal and pelvic PET results, and/or a decrease in the number of PET referrals for all oncologic applications. Successful tumor imaging of the abdomen and pelvis with PET requires proper patient preparation. Simple placement of a Foley catheter and irrigating the bladder with saline using a three-way catheter often proves inadequate. The technique we have described is a simple and effective means of eliminating many of the image artifacts originating from the kidneys, ureters and bladder. Backfilling the bladder with saline further assists in the interpretation of pelvic pathology by providing a well-defined anatomic landmark and by diluting residual bladder activity. Considerable care must be taken to ensure that normal structures are not mistaken for pathology and that artifacts are minimized to lend clinical confidence to results. This method also may be useful when performing SPECT imaging of the pelvis where bladder activity is also a problem.

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